Chapters 4 & 5
Macromolecules

Every living organism
On this planet
Is made of the same
4 macromolecule
Building blocks
Chemical Evolution

• Proposed by Alexander I Oparin in 1923.
• Currently has 4 steps:
  – Chemical evolution began with the production of small compounds with reduced carbon atoms
  – Simple compounds reacted to get mid-sized molecules called amino acids, sugars, and nitrogenous bases
  – Midsized molecules linked to form large molecules like proteins & nucleic acids
  – ****Life became possible when one of these large, complex molecules became able to make a copy of itself
Chemical Evolution

Electrical spark
(Lightning)

H₂O, CH₄, NH₃,
H₂, CO

gases (primitive atmosphere)

Cold water

Condenser

Cooled water
(containing organic compounds)

Sampling probe

Sampling probe

Water (ocean)

Heat source

Electrodes

to vacuum pump

Direction of water vapor circulation

MILLER & UREY
Macromolecules of Life

• Every living organism on this planet is composed of 4 macromolecules.
  – The energy molecules:
    • Carbohydrates (Sugars)
    • Lipids (Fats)
  – The structural molecules:
    • Protein (Main molecule of life)
    • Nucleic Acids (DNA & RNA- Informational)

• These molecules existed in the prebiotic soup and at some point built the first living thing
Components of a Nucleotide

NUCLEOTIDE

- Phosphate group
- Sugar
- Nitrogenous (Contains a nitrogen) Base

Phosphate
Sugar
Nitrogenous Base
TRIPHOSPHATE
RIBOSE SUGAR
Sugar

• **Sugar** is categorized as an organic compound with a **carbonyl group**
  – C=O
How do Nucleotides Polymerize

• It starts with a phosphodiester linkage
  – This condensation reaction is the formation of the bond between the phosphate group of one nucleotide and the hydroxyl group of the sugar component.

• If the nucleotides involved contain the sugar RIBOSE, the polymer is called RNA

• If the nucleotides involved contain the sugar DEOXYRIBOSE, the polymer is called DNA
DNA’s Sugar-Phosphate Backbone

Ribose - used in RNA  Deoxyribose - used in DNA
RNA’s Sugar Phosphate Backbone
Count Your Primes
Base Pairs

Purines

Adenine "A"

Guanine "G"
Base Pairs

Pyrimidines

Thymine
"T"

Cytosine
"C"
PROBLEM with DNA

- DNA seems like a great suspect for the first polymer to reproduce itself

- ONE PROBLEM

- DNA is WAYYYYYyyyy too simple and stable of a template act as a catalyst and fuel self replication

- In fact, never has it been observed to act as a catalyst in the laboratory…
  - Which means, without an external energy source, DNA is very unlikely to be able to sustainably self replicate
RNA as a suspect for life

What about RNA???

• ....as a possible suspect for life's "roots"
• ... ... Or maybe first we should ask...

What is RNA?
DNA vs. RNA

• Both have a sugar phosphate backbone formed by phosphodiester linkages
• However there are 2 main differences:
  – The pyrimidine base THYMIN does not exist in RNA. Instead, RNA contains the closely related pyrimidine base URACIL
  – The sugar in the sugar-phosphate phosphate backbone of RNA is RIBOSE, not deoxyribose as in DNA
RNA

• The second point is CRITICAL when comparing the two (and understanding RNA)
• The hydroxyl group on the 2`-carbon of RIBOSE is MUCH more reactive
• This is the main difference that makes DNA stable and RNA reactive
• The absence of Thymine and presence of Uracil makes them easy to distinguish
RNA Hairpin

- Another difference between RNA and DNA is in their secondary structures.
- Very often, RNA is denoted as a single strand (where DNA is a double strand).
- However, RNA can appear to be a double stranded helix during what is called a Hairpin.
- This is when the secondary structure of RNA loops and forms a double stranded “stem”.
RNA Hairpin
Hairpins

• These form WITHOUT energy input because they exergonic
  – Hydrogen bond formation is exothermic and exergonic

• Though they do release the entropy of the strand, this is a “flag” for being the first reproducing molecule because it can release bond energy required for replication
RNA Contains Information

- RNA contains a sequence of bases that is analogous to the letters in a word
- This allows it to carry information
- Because hydrogen bonding occurs specifically between A-U and G-C in RNA, it is THEORETICALLY possible that it can make a copy of itself
When considering the replication process, it is important to know the terminology for each strand:

- **Template Strand**: Original strand
- **Complimentary Strand**: New strand being created

It is called this because it needs to match the template as a perfect compliment.
DNA Replication

• DNA is not only an exceptional information carrying molecule; it is also structurally made to replicate itself
  – Through simple base pairing, DNA basically has two copies at all time
  – All DNA polymerase (the protein that helps form the new DNA strand) has to do is unzip the molecule
    • Once the molecule is unzipped, deoxyribose nucleotides will naturally make new base pairs
DNA polymerase works in a 5’-3’ direction.
Leading & Lagging

• Where the DNA strand is unzipped is known as the **replication fork**
  – From this fork, each of the original strands acts as a template for replication

• **The leading strand** allows the new strand synthesized complementary to it, to be synthesized 5' to 3' in the same direction as the movement of the replication fork.

• **The lagging strand** starts away from the replication fork (moving towards it) and adds small fragments to template strand called **Okazaki fragments**
  – DNA polymerase works in a 5’-3’ direction
A lil bit of energy

- In order for the template strand to make a new complimentary strand an input of energy (a small amount) is required
- Compared to a protein, RNA is VERY STABLE and not (very) catalytically reactive
- However, in rare occurrences, RNA can form the necessary tertiary structures and transition forms for chemical catalysis to occur
The unlikely catalyst

- If RNA can form the necessary tertiary structure to behave like a catalytic protein than it should be able to break bonds to release energy
- If the bonds break and the free energy is released, the energy could be absorbed by a templating molecule
- This molecule would then have the necessary energy to form the necessary bonds of a complimenting structure, and could affectively replicate itself
Its alive…. ITS ALIVE!!

• This would adequately meet both of lifes (current) requirements
  – Replication (Reproduction) would occur
  – Energy would be used to effectively carry out the replication process

• Then, over a great deal of time, these replicating molecules would change (due to simple mutation) and likely increase in complexity

• Because RNA carries a code, complexity from mutation would seem very likely…
DNA is Formed From Genes

• In biochemistry and genetics it has been genetic dogma that genes are parts of DNA

• However, recent research is showing that it may be more accurate to say that genes form your DNA…
  – To explain this story we have to think back a long long time ago… Perhaps about 4.5 B.Y.A.
The first “Genes”

• THE RNA WORLD HYPOTHESIS:
  – The prebiotic soup was composed of a multitude of compounds, most importantly:
    • Protein, Nucleic Acids, Lipids, & Carbohydrates

• All of these molecules naturally form bonds in the presence of energy.

• The bond forming would last until the molecules were broken down by a different reaction (2\textsuperscript{nd} law of thermodynamics)
The RNA WORLD

• Through a generic form of natural selection, only macromolecules that resisted degradation from entropy would exist longer than any other

• Over time, the soup became dominated by macromolecules that were resistant to degradation
  – This domination would be brief in the large scheme, because the molecule lacked the ability to template replication
RNA Takes the Lead

- At some point, an RNA molecule (through random chance and bonding) Hairpin loops forming a ribozyme (RNA Catalyst)
  - This molecule can split (through catalysis) and can form a template with free floating nucleotides (through base pairing)
  - This allows it to rapidly replicate itself, giving it a chance to increase its numbers against the tide of entropy
  - Over time, this replicating RNA becomes dominant in the prebiotic soup
Now to Battle Entropy

• The RNA molecule, now commoner than any other molecule in the soup, over time will develop copying errors

• These errors, called mutations, cause some RNAs to differ from others
  – Some strands get longer, some get shorter, and most importantly, some begin to interact with other macromolecules
  – Some RNA molecules begin to interact with amino acids, forming bonds that eventually lead to the first tRNA (Transfer RNA)
  – Some become intertwined with proteins, forming elaborate machines called ribosomes
  – Some interact with free lipids forming fat bubbles that protect them from the degradation of entropy
The Battle Continues

- Due to the RNA molecules success, the amount of free nucleotides in the prebiotic soup decreased dramatically.
- As the RNA molecules became more and more different, (and free nucleotides became more rare in the soup) many of them began **degrading other RNAs for free nucleotides**
  - Similar to a predator degrading its prey for nutrition
- Now it is a game of pure natural selection…
RNA to DNA

– The pressure was on RNA to become resistant to degradation (from entropy and predator RNAs)
  • RNA was much safer from degradation in the hairpin loop form, but couldn’t sustain this structure because of the nature of RNA (DICER naturally cuts it)

– One replicating RNA molecule had a writing error that allowed for a different Thymine nucleotide to replace the common Uracil (Only possible when the Sugar on the S-P backbone loses an oxygen)
  • This one change allowed for the RNA to hairpin loop, and remain looped in the form of a double strand

– This new double stranded RNA with a thymine in the place of a uracil (called DNA) was extremely resistant to entropy (Stable) and made replication even easier
And Then There Was DNA…

- DNA was far more stable which allowed for a decrease in mutations
  - Although this likely slowed down the rate at which differentiation occurred, it also dramatically decreased the chance that molecule would be degraded
- Over time, this molecule began to differentiate and compete much the same way the early RNA molecules did
  - Some DNA molecules utilized the tRNA molecules to create strands of amino acids that it could use to become more specialized
  - Others utilized lipids to form strong outer barriers that were only permeable to things the cell needed
- A new world, a world of **cells**, was beginning to emerge!
Genes make DNA

- Each new useful (or negative) change that occurred within these first nucleic acids would today be called genes.

- Selective pressure made it so only the most beneficial “gene-containing” “organisms” were able to make successful offspring.
  - But remember, the “organism” we are referring to is really just the same collection of genes that formed the RNA strand.

- The genes that formed the more successful organism dominated the less successful and replaced them…
The Selfish Gene

- As natural selection pressures grew stronger, it became essential for the genes to cooperate and work together which allowed them to specialize
  - This cooperation led to the formation of chromosomes (Groups of genes working together)
  - Even internally genes fought to insure they would be successful in the next generation
    - IE: XY gene competition; Formation of placenta
- Over time, this led to the formation of basic and eventually complex cellular organisms
DNA → Protein

• Because DNA was an information carrying molecule, it made it possible to “code for” **amino acid chains**
  – This worked using a rudimentary machine called a ribosome and tRNA

• Any DNA molecule that could manipulate protein had an advantage
  • (protein is a powerful structural molecule)

• The better it could utilize protein, the better its chance of surviving…
  • Which began the transition of Protein being the “functional unit” of macromolecule life
Amino Acids

• The cells in your body produce tens of thousands of distinct proteins
• Most of these proteins are composed of roughly 20 different amino acids (all with very common structures)
• In all amino acids a carbon atom is bonded to an amino group, a carboxyl group, a side chain, and a hydrogen atom
Side Chains

• The side chain in a compound is abbreviated as “R”
• Chemists use this symbol to indicate additional atoms
• The 20 amino acids found in organisms are different because of their side chains
  – There are an infinite possible # of AA, depending on the side chain
Nature of Side Chains

• The “R” group on an AA will be either Polar or non-polar
  – If it is Polar, then it is considered water-loving and is hydrophilic
    • This means that they **do** have a charged or electronegative atom capable of forming a hydrogen bond with water
      – This will dissolve in water
  – If it is Nonpolar, then it is considered water-hating and is hydrophobic
    • This means that they **do not** have a charged or electronegative atom capable of forming a hydrogen bond with water
      – This will coalesce in aqueous solution
3 types of Isomers

- Molecules that have different structures but the same molecular formula are called **Isomers**

- **3 types of Isomers:**
  - **Structural Isomers:** same atoms but differ in the order in which covalently bonded atoms are attached
  - **Geometric Isomers:** same atoms but differ in arrangement atoms on either side of a double bond or ring
  - **Optical Isomers:** same atoms but differ in the arrangement of atoms or groups around a carbon atom that has FOUR different groups attached
Structural Isomers
Geometric Isomers
Optical Isomers

• This “isomerism” is to do with the arrangement of the atoms in space.
• It arises through the presence of a Chiral Center.
• The Chiral Centre is an atom connected to Four Different Subsituent Groups
• Optical isomers are Non Superimposable Mirror Images of each other; a set of optical isomers are called enantiomers
Optical Isomers

- Most amino acids have optical isomers
- ANY carbon atom with 4 Substituent groups attached to it HAS an optical isomer
- Every amino acid (except glycine) exist in 2 forms, but only one of these forms are found in living cells!
- In cells, only the “left handed” optical isomers exist
- Why is this? Can we explain it with the theory of chemical evolution??
Knowing Your Enantiomers

• In the mid 1900’s a drug called Thalidomide shook the world & the food and drug administration

• The drug was used to reduce pain in pregnant women

• However, the enantiomer of the drug (which can be synthesized in your body once you take the drug) caused SEVERE birth defects
  – Children born w/o arms or leg
Thalidomide

• Despite being a remarkable pain reliever, thalidomide was quickly removed from the shelves.

• Recently it has returned as a pain killer for types of leprosy and for pain treatment in critical cases.

• It even has hopes as an anti-cancer drug.
  – Needless to say, the FDA is closely monitoring its uses.

• Thalidomide paved the path for the advanced drug testing used today.
• A molecular subunit such as an amino acid, a nucleotide, or a sugar is called a **Monomer**

• These monomers bond together to form a **Polymer** in a process known as **Polymerization**

• Amino Acids “polymerize” to form proteins

• A **Protein** is a linear macromolecule
How Does a Cell Make Proteins?

• The process of protein synthesis is called **translation** (This comes 2\(^{nd}\))
  
  – **Translation** refers to the process of converting the “3-nucleotide RNA codons” into amino acids and then into amino acid chains

• The RNA molecule comes out of the nuclear envelope after it is **transcribed** from DNA (This happens 1\(^{st}\))
  
  – **Transcription** is the process of creating an RNA strand from a template of DNA nucleotides
The Peptide Bond

• AAs polymerize through peptide bonding
• When a bond forms between the carboxyl group of one of the AAs and the amino group of another, polymerization takes place
• This is called a Peptide Bond
The Peptide Bond

• This bond is exceptionally strong because the electrons are shared by the carbonyl group and the peptide bond
• This sharing gives the characteristic of a double bond
• This prevents the compound from rotating
The Peptide Bond

• Multiple peptide bonds in a compound are called **Polypeptides**

• They are numbered from the **N-terminus**, which is the start of the chain when proteins are synthesized within a cell

• If it contains less than 50 AAs it is called an **Oligopeptide**
Protein Structure

- Proteins will have a **Primary Structure** that is the unique sequence of AAs.
- Approximately 10,000 billion different primary structures exist.
- A protein's **Secondary Structure** is created by hydrogen bonding along the peptide bonded backbone of the protein – NOT the side chain.
- The **Tertiary Structure** results from the interactions between the R-groups or between the R-groups and the peptide backbone – This give the protein shape.
The Quaternary Structure

• This is the end view structure for polypeptides
• It occurs with the interactions of the various polypeptides as subunits
• These react with various R groups or the polypeptide backbone to form the final structure
  – This “view” is what is used to consider how various proteins interact.
THE HUNTINGTON STORY

The importance of perfection in DNA replication, RNA transcription, and protein translation.
Genes Don’t Cause Disease

• In genetics, we have an extremely bad habit of explaining genes by the genetic diseases that are caused by their mutation—Bob has Wolf-Hirschhorn syndrome because he has the Wolf-Hirschhorn gene...

THIS IS EXTREMELY INACCURATE... WE ALL HAVE THE *Wolf*-Hirschhorn GENE, HOWEVER PEOPLE WITH *Wolf*-Hirschhorn syndrome HAVE A DAMAGED OR MISSING *Wolf*-Hirschhorn syndrome GENE...
Wolf-Hirschhorn syndrome

• People who have Wolf-Hirschhorn syndrome are extremely rare and the disorder is so severe that they usually die very young
  – For all the rest of us, having an intact and working Wolf-Hirschhorn gene keeps us alive and healthy.
  – It’s pretty much a big deal!!!!!(essential protein)
Wolf-Hirschhorn syndrome
The gene...

• The *Wolf-Hirschhorn gene* must do something required for the correct development of a living being.

• The gene, is a simple repeated codon: CAG, CAG, CAG, CAG, CAG, CAG
  – CAG codes for the AA Glutamine

• Sometimes it is repeated 6 times…
  Sometimes more than a hundred times…

*Your destiny, your sanity, and your life depend on this repetition*
DNA Must be Perfect

- If the word is repeated 35 times or fewer, you will be fine… (Most of us have about 10-15)
- If you have 39 repeats or more you will in midlife slowly start to lose your balance, slowly start losing the ability to take care of yourself, and eventually die prematurely
- The disease begins with a decline of neurological ability, followed by jerking limbs, and eventually depression and full dementia.
- There is no appeal…
- It takes between 15 and 25 years to run its course
Huntington's Chorea

• The age and severity that the disease will occur is entirely dependent on the # of repetitions of the CAG codon in one gene on one chromosome…
  
  • It doesn’t matter if you smoke, work out, eat healthy, do drugs, are a couch potato, or are a picture of health…

  – If you have 39 repeats, you have a 90% chance of dementia by 75 and will have the first symptoms by 65

  – If you have 40 repeats, you will succumb by 59

  – If you have 41 repeats, by 54

  – Until those with 50+ repetitions will lose their minds at roughly 27 years of age
If we stretched your chromosomes out end to end around the entire planet, the difference between a healthy life and a death sentence of insanity is no more than an inch in length...
Genetic Death Sentence

• The onset of this disorder occurs usually after the person has already passed on their genes to their children
  – It is mostly outside the realm of natural selection

• It is a dominant gene, making each child with an infected parent have a 50% chance of the disorder
  – Truthfully an inaccurate comment… Either they have the gene, or they do not, so they have a 0% chance… or a 100% chance
Mistakes in Copying

• It seems that the cause of these repeats has to do with something called genetic anticipation
  – This occurs when the reading frame slips during DNA replication and loses count of how many CAG codons have already been copied
    • Your body never wants to delete a gene, and usually an extra copy is far less detrimental
      – It is much easier to count 10-15 CAGs then 30, 50, or 100.
  • These CAG codons code for a Glutamine AA
Small Error, BIG MISTAKE

• The glutamine amino acids are normally at the end of a string of amino acid that make a necessary protein for the body to function
  - We know this because W-H syndrome

• The additional Glutamines (in Huntington’s) form a sticky mass that eventually strangles neurons, causing neural degeneration

• As the body grows it copies the DNA for each new cell, and each new DNA copy is at risk for anticipation errors
  - This is why a person with Huntington’s have no issue early in life, but as the repeats get longer and longer eventually begin to destroy the brain
Magnitude of an Error

• The magnitude of this copy error, and many other known similar copying errors become relevant when considering cells that reproduce rapidly
  – Brain thalamus cells reproduce extremely slowly and are rarely replaced throughout life
    • Even in a Huntington's patient the thalamus does not produce proteins with extensive glutamine AAs
  – In areas like sperm production cells, these anticipation errors quickly become extensive
    • Older males tend to pass on more severe forms
Huntingtons
Huntington’s Knowledge

• Nearly none of this information was known 5 years ago
• The knowledge of this copy error and the huge number of similar diseases caused by the proteins formed from it (like fragile X syndrome) are just now being understood
• Still to this day, we have this knowledge but have not yet found the cure… … …
• Is this knowledge beneficial?
Protein Functions

- **Defense**: Antibodies
- **Movement**: Motor, contractile, and helper proteins allow for cell movement (inside & out)
- **Catalysis**: Proteins called enzymes speed up reactions
- **Signaling**: carry and receive inner cell signals
- **Structure**: Cellular mechanical support
- **Transport**: Are the doorways into a cell that allow for entering and exiting of molecules
Cell Signaling

- Cells do not have the ability to “talk” to each other
- Yet each cell must know what is occurring in other cells and other areas of the body
- In order to do this cells create specific signal proteins that are used to communicate
- These proteins are crucial to the body being able to maintain homeostasis
Signaling
Cell movement

• Proteins build the microtubules that allow for chromosomal movement during mitosis & meiosis
• They allow for the unwinding and winding of DNA in a chromosome (ie: Histones)
• They build the primary structures of cell movement apparatuses such as cilia and flagella
• By manipulating the protein cytoskeleton they allow individual cell movement
Antibodies

• When your body is infected with a parasite and the parasite is defeated by your immune system, special proteins will help your body recognize future infections.
• Your immune system can form special protein structures that match receptors on the parasite
• These receptors will signal the parasites presence in a future infection and signal an immune response.
Antibodies

Antibody inhibition
Proteins as cell transport

• Trans-membrane proteins are the “hallways or doors” that allow large molecules to enter or leave a cell.
• This is the only way items like glucose can enter the cell, and how waste products can leave
• They also can function as active transport pumps, to move items against a concentration gradient.
Cell Structure

• Proteins make up the microtubules and microfilaments that give a cell its structure.
  – Incorrectly formed or mutated cell microtubules can dramatically change a cell or organelles shape
  – IE: Sickle Cell Anemia

• It allows for tension to exist in a cell and can even assist in cell movement
Proteins as a Catalyst

- For the body to function properly and efficiently, certain reactions must use a protein catalyst to lower the activation (start) energy.
- These proteins are referred to as **Enzymes**.
- Enzymes are very specific in their activity and use specific **active sites**.
- Once the enzyme active site binds (induced fit) to the substrate, it goes through a conformational change.
  - This can cause reactions to occur and/or new substrate to form.
Enzyme Action

- **Initiation**: Reactants bind the active site in a specific orientation.

- **Transition State Facilitation**: Interactions between enzyme and substrate lower the activation energy required.

- **Termination**: Products have lower affinity for active site and are released. Enzyme is unchanged after the reaction.
Catalyst Regulation

- **Competitive Inhibition**: a molecule that is a similar size or shape as the enzyme binds in the active site with little to no reaction.

- **Allosteric Regulation**: Regulatory molecule (enzyme) binds at a site that is not the activation site.

- **Coenzyme**: Sometimes an activation site requires an additional molecule to bind with the enzyme in order for it to fit the activation site.
Everything Fits Perfectly

• In many enzyme reactions or protein regulations the substrate must fit perfectly
• It must have the correct charge, move in at the correct orientation, and often even bind with the correct membrane proteins
  – It is a very delicate process… for good reason

• PROTEIN STRUCTURE DICTATES PROTEIN FUNCTION!
Creatine

• Creatine is naturally produced in the human body from amino acids primarily in the kidney and liver.
  – “Non-essential” protein… You make it.
  – It is manufactured in the human body from L-arginine, glycine, and L-methionine (all AA)

• Built by the bodies natural signal processes, creatine is how a body cell signals a need for water.

• Like all body signals, it is closely monitored, and inhibited if over produced.
Protein Resiliency

• Protein function is dependent on structure, and protein structure can be broken down
  – When excessive energy is added to a protein (boiling) or taken away from a protein (freezing) it can **denature** the protein
    • A denatured protein loses some or all of its shape and often its function

• Remarkably, this is not true of all proteins.
  – A special protein structure, known as a **Prion**, not only can withstand denaturing, but it also nearly indestructible by chemical standards
  – Additionally, prions can cause normal proteins to reform their structure to look similar to the prion
Prions

• Currently we are still unsure what the function of a prion
  • They are remarkably useful in the formation of vaccines
    – However, we do know that most known prions can cause serious diseases (especially neurological) in all sorts of organisms
      • They appear to form protein globs that strangle the cell (when they induce other proteins to form similar globs)
      • Even more frightening is the idea that they are completely immune to all known sterilization techniques

• Prion disease cause the similar diseases: Scrappy (sheep), Kuru (Papua, New Guineans), Mad Cow Disease (Cows, Felines, and Humans), CJD (Humans)
  – The diseases are also remarkably picky in who is affected
The Energy of Life

Carbohydrates

Basically is a chain of Carbons, covalently bonded to Hydrogen and Hydroxide.
Carbo-Hydrates?

• Carbohydrate chemical formula is generally:

\[-(\text{CH}_2\text{O})_n\]

• \(n\) = the number of “carbon-hydrate” groups
How do we use them?

• Carbohydrates, like any energy storing compound, must catalyze in order to release their energy.
• Just as protein shape is required for protein function, carbohydrates are specific to catalyzing proteins (enzymes)
• Just as there are hundreds of thousands of possible carbohydrates, there are at least that many catalyzing proteins (specific to the carbohydrate)
Aspartame and Splenda

• Aspartame is a chemical derivative of sugar
  – Its goal is to trigger your “taste buds” without supplying your body with any usable energy

• Splenda is actually an indigestible form of sugar that still triggers your bodies taste sensors
  – Usually your body treats this sugar as a fiber
Getting the Energy Out

• As stated earlier, the energy within a carbohydrate is released through protein catalysis and enzymatic reactions
• The most important enzyme in the catalysis of alpha-glycosidic linkages is a protein called phosphorylase and a protein called amylase
• Both are involved in hydrolysis (break down with acid) reaction
Phosphorylase and Amylase

- **Phosphorylase** is responsible for breaking the glycosidic linkages in glucose
- **Amylase** is responsible for the hydrolysis of starch molecules
  - Amylase is produced in human saliva
  - It is believed to be one of the main reason for the human diversity of taste
  - It also remarkably kills the HIV virus
Polysaccharides

- Polysaccharides form when monosaccharides are linked together
- The simplest Polysaccharide is when two sugars link, called a disaccharide
- Simple sugars polymerize when a condensation reaction occurs between 2 hydroxyl groups
- This polymerization occurs through a process called Glycosidic Linkages
High Fructose vs. Glucose

• Keep in mind that the amount of energy a sugar molecule can hold is dependent on the # of C-H bonds.
• The more bonds the more energy.
• This is why some sugars give off substantially more Calories of energy than others.
  – This is not always easy to discern by simply looking at the “nutrition facts” on the side of the bottle or back of the package.
Starch & Glycogen

- When plants store their polysaccharides, they store them as **starches**
- When animals store their polysaccharides, they store them as **glycogen**
- Both are basically a densely packed polysaccharide
- Both are very high energy and require specific enzymes to break them into simpler sugars
Different Polysaccharides 2 Know

- **Starch** - Storage of sugars in plants
- **Glycogen** - Storage of sugars in animals
- **Cellulose** - Makes up the cell wall of plants.
  - The most abundant polymer on earth
- **Chitin** - Stiffens the cell wall of fungi and many algae
  - Very similar to cellulose
- **Peptidoglycan** - Found in bacteria cell walls
  - The most complex polysaccharide
- **Glycoprotein** - used in cell recognition and cell signaling
Cell Recognition

• Carbohydrates DO NOT store information
• However, that does not mean that they are not able to relay information within a cell
• A special covalently bonded carbohydrate-protein molecule called a **Glycoprotein** is used in cell recognition
• It is a relatively short chain of sugars that extends from intermembrane proteins in the lipid bilayer (cell membrane
Glycoprotein

• Glycoproteins are the **key** molecule in cellular recognition and cell to cell signaling
• It directly identifies a cell (or membrane bound substance) as belonging to the body or not
• Essential in your immune systems ability to protect against foreign substances
• Also labels what type of cell it is (ie: nerve)